Environment Canada / Environnement Canada
Conservation and Protection / Conservation et Protection

A State of the Environment Fact Sheet

Contaminants in Herring Gull Eggs from the Great Lakes

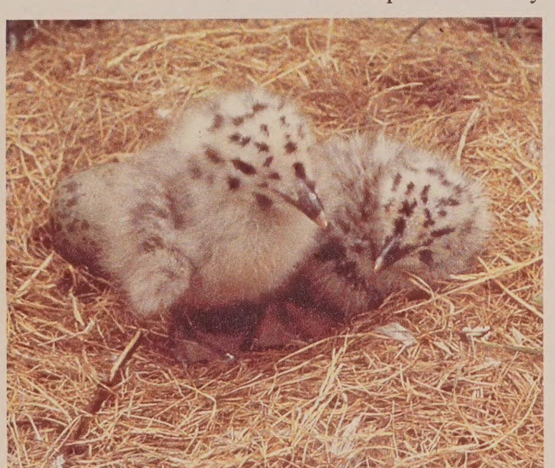
A program to monitor organochlorines in the eggs of Herring Gulls and to study their effects began in 1971

Introduction

In 1969 a biologist went to Scotch Bonnet Island in Lake Ontario. He counted about 100 pairs of nesting Herring Gulls on this small island, but only about 12 chicks; there should have been at least 100 or about one chick per nest. Where were all the young? What had happened to them?

This sobering visit to Scotch Bonnet Island was one of the events that led to the establishment, in 1971, of a program to monitor persistent toxic chemicals in the eggs of Herring Gulls and to study the biological effects of these contaminants on waterbirds of the Great Lakes. This fact sheet includes the results of monitoring up to 1989. The monitoring and research is continuing in the 1990s.

In the early 1970s, the Herring Gulls and other waterbirds living in the Great Lakes, especially populations located in Lake Ontario, were among the most heavily contaminated in the world. With the advent of legislative controls and restrictions on the use and disposal of many persistent toxic chemicals, concentrations found in fish-eating birds began to decline after the mid-1970s.


Pierre Mineau

Herring Gull chicks

This fact sheet describes changes in the levels of four organochlorine chemicals (see box on page 8) in Herring Gull eggs between 1971 and 1989 and the biological effects these chemicals have had on waterbirds. Two of the substances that are reported on here originally entered the environment as organochlorine pesticides: dieldrin and dichlorodiphenyldichloroethylene (DDE), which is a breakdown product of the pesticide dichlorodiphenyltrichloroethane (DDT). The other two chemicals are polychlorinated biphenyls (PCBs) and a dioxin known as 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD). The fact sheet also explains the reasons for this ongoing study and how the results relate to the Great Lakes environment of which humans are a part.

Biomagnification

Organochlorine compounds, because of their characteristic chemical structure, resist bacterial and chemical breakdown processes in the environment. When they are applied as pesticides or are otherwise released in the environment, they do not quickly break down into harmless compounds as many less persistent synthetic chemicals do; instead, they retain their chemical structure and, because they are not very soluble in water, they evaporate into the air or attach themselves to soil particles. As vapour or dust they may be carried great distances, and re-deposited by rain and particulate fallout onto land and water surfaces.

From the water surfaces, these substances tend to be absorbed into the fats of small organisms called plankton, thereby entering the lowest level of the food web. As larger animals

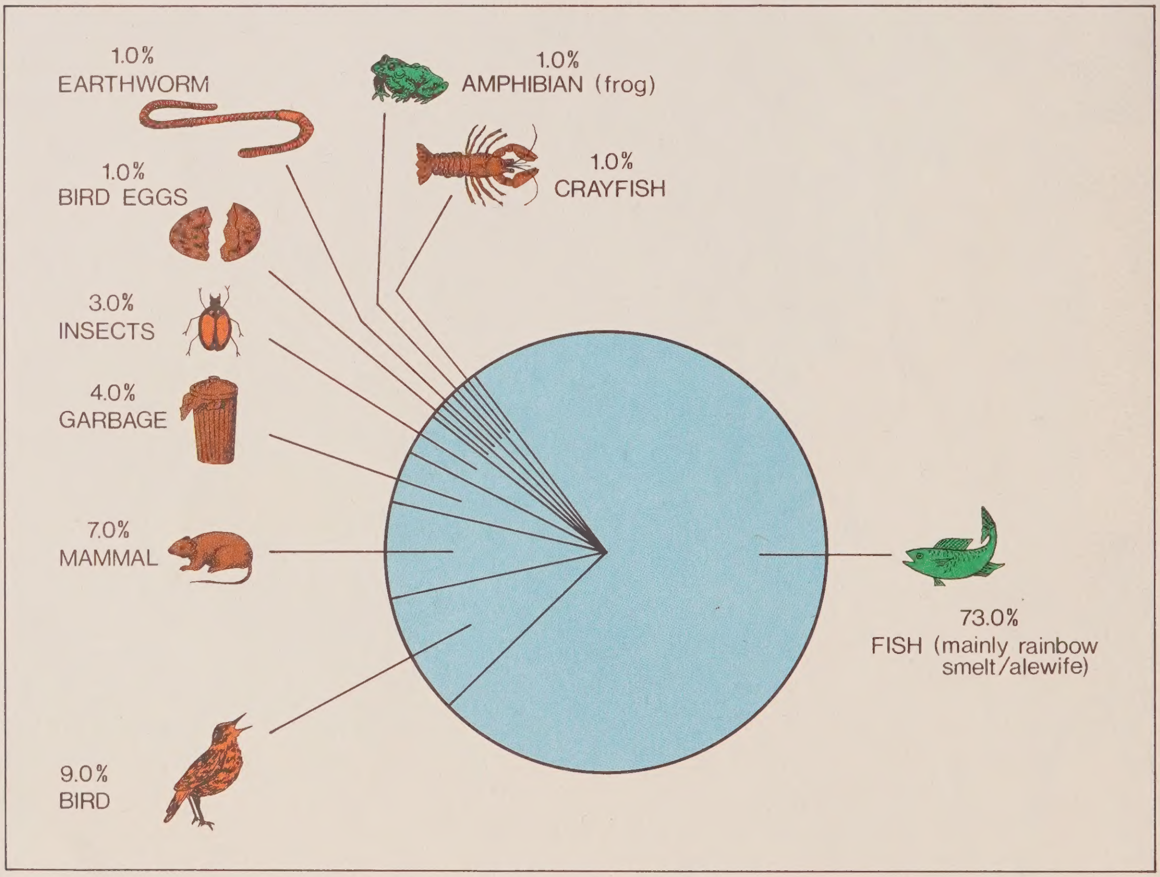
Think Recycling!

and fish eat the smaller animals, the contaminants pass up the food web. Because these substances enter the fat of an organism, while the digestible materials the organism has consumed are used for energy or are excreted, the organochlorines can build up to higher concentrations at each step in the food web. This steady increase of contaminant concentrations in animal tissues at each higher step in the food web is known as biomagnification.

Fish-eating birds, such as the Herring Gull, are near the top of the food web, only top predators, like the Bald Eagle, which eats Herring Gulls and other foods, build up higher concentrations. As Figure 1 shows, the Herring Gull eats many prey, including fish, mammals, insects, birds and bird eggs, amphibians, earthworms, and crayfish as well as garbage. Fish, especially alewife and rainbow smelt, is the most important food item in the gull diet; it is also the most contaminated.

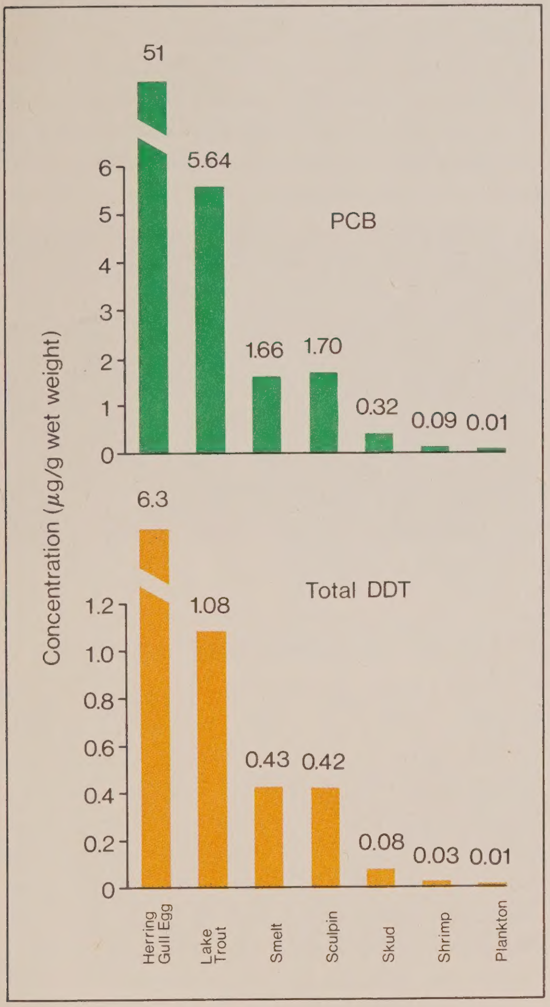
This biomagnification process has been demonstrated in research studies that measured PCBs and DDT in different animals in the food web. In Figure 2, the animals living closest to or in the lake sediments are on the right-hand side of the graph. These animals contain the least contamination. The plankton, the crustaceans (such as freshwater shrimp), and the amphipods (such as the freshwater skud) are tiny animals that obtain nutrients from floating particles and represent the lowest tier on the food web. These animals are then consumed by fish, such as sculpin, which live near the bottom of the lake, or smelt. Eventually these fish are eaten by predators such as lake trout or gulls. The contaminant levels are magnifying at each step of the food web. Gulls tend to accumulate higher

Figure 1
Percentage occurrence of food items in the diets of Herring Gulls that breed in colonies on the Great Lakes



concentrations than trout because gulls, unlike trout, are warm-blooded animals, and require more food to maintain their body temperature. The more food eaten, the more contaminants the gull will absorb. Top predators, such as people or Bald Eagles, that consume lake trout or gulls, will biomagnify the contaminants even further.

Figure 2
Biomagnification in a food web in Lake Ontario



The Herring Gull as a monitor of contamination

An animal or plant that accumulates organochlorines from the area in which it lives can be used as a "monitor." Some organisms possess certain characteristics that make them particularly useful for this purpose. For example, an animal that lives year round in the area to be tested almost certainly picked up any foreign substances in its tissues from the test area. Of the various species of fish-eating birds that might make good monitors for the Great Lakes, the Herring Gull is the only one that stays on the lakes all year round. Other colonial waterbirds of the Great Lakes such as terns, cormorants, herons, and other species of gulls, migrate annually and may also pick up contaminants from their wintering grounds away from the Great Lakes.

Also, the Herring Gull is a predator. This means it concentrates contaminants in its body. Contaminants that are difficult to measure in water or in animals that feed only on plants are biomagnified to high levels in Herring Gulls and are easily measured.

Brian Morin

Herring Gull adult

The colonial nesting habits of this gull also make it a good choice for monitoring organochlorines. Its eggs are easily sampled within the colonies and by using eggs it is possible to measure contamination without having to kill adult or young birds. Only 10 to 13 eggs per year (one per nest) are collected from each colony because there is little variation in contaminant levels among eggs within the same colony. Also,

contaminant analysis is very expensive, which prohibits the testing of large numbers of eggs. Taking these eggs from a colony should not affect the population. Gulls generally lay additional eggs to replace any that are lost early in the nesting season and their populations have remained large throughout the 1970s and 1980s.

John Struger

Herring Gull nest with eggs

The Herring Gull breeds in all five Great Lakes and in other regions of Canada and of the world. This allows direct comparisons of contaminant levels and types to be made among all of the Great Lakes and sites outside Canada. This has made Canada's Herring Gull egg monitoring program one of the most useful, long-term monitoring programs in the world.

Effects of organochlorines

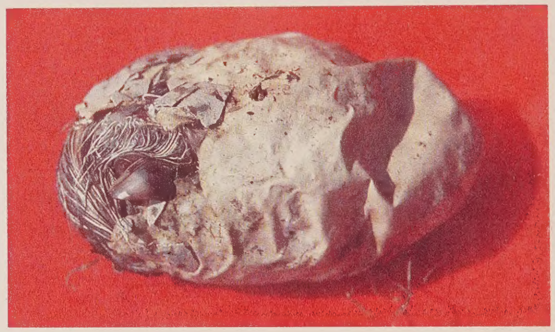
Problems such as reduced hatching success and eggshell thinning have been reported for fish-eating birds

The presence of toxic chemicals in the Great Lakes food web has coincided with poor health and reproductive problems of many of the fish-eating birds living there. Problems such as reduced hatching success of eggs, eggshell thinning, deformities in embryos and hatched young, and abnormal adult behaviour during nesting have been reported in several species of fish-eating birds in the Great Lakes. These effects have occurred when high levels of certain organochlorines have been found in birds' eggs. Herring Gull eggs become contaminated because the fat-soluble organochlorines move into the eggs in the fat that is required to produce the yolks.

Eggshell thinning

Eggshell thinning was the first reproductive problem related to contaminants identified in birds on the Great Lakes. The effects were most obvious in Double-crested Cormorant and Black-crowned Night-Heron populations. Numbers of these species had plummeted in the early 1970s mainly because their eggshells were so thin that the eggs would break when the parents began to incubate them.

The thinning was caused by the presence of DDE in the female birds. Eggshells are formed within the female bird and are made of calcium carbonate. The bird creates calcium carbonate by combining calcium and carbon dioxide in its system and this is aided by enzymes. DDE inhibits the action of enzymes necessary in this chemical reaction. As a result, the eggshell does not contain as much calcium carbonate as it should, and is much thinner than normal. Therefore, the shell is not strong enough to support the female bird as she incubates the egg.



Chip Weseloh

Thin-shelled Herring Gull egg

Herring Gull population changes

The Herring Gull did experience some decreases in its populations in the 1970s. Studies of gull colonies showed that the number of eggs hatching and chick survival were low in Lake Ontario in 1972. At colonies in eastern Lake Ontario only 0.10-0.21 chicks per nest fledged (successfully left the nest) and in Lake Erie, fledging success was 0.25-0.52 chicks per nest. Normal fledging success was estimated to be 1.0 chicks per nest in colonies outside the Great Lakes. In 1972, several contaminants were at their highest levels in Lake Ontario as compared to levels in the other Great Lakes. Populations have since recovered and this is considered to be a result of regulating the use of organochlorine chemicals.

Herring Gulls were behaving differently at their nests in colonies on different lakes. Herring

Gull nests on Lake Ontario colonies were unattended longer than nests in less contaminated "clean" colonies. This inattentiveness at the nests caused substantial cooling and overheating of the eggs, and increased egg loss, resulting in low hatching success.

Uncontaminated eggs from a "clean site" in New Brunswick were brought to Lake Ontario and placed in Herring Gull nests while Lake Ontario eggs were placed in New Brunswick nests. These studies revealed that the clean eggs from New Brunswick had poorer hatching success when placed in Lake Ontario nests. The eggs from Lake Ontario had better hatching success when placed in New Brunswick nests. But eggs from Lake Ontario in New Brunswick nests did not hatch as successfully as clean eggs from New Brunswick in their natural nests. It was concluded then that Lake Ontario hatching success was affected by both abnormal parental behaviour and contamination within the eggs.

Biochemical changes in liver function

Liver function in Herring Gulls in the Great Lakes is also abnormal. This problem coincides with their exposure to environmental contaminants. Most foreign chemicals entering the gull's body are attacked by detoxifying enzymes in the liver and rendered harmless. Gulls from more polluted areas have increased detoxifying enzyme activity in their livers, elevated levels of porphyrins (compounds that only build up in the liver under abnormal conditions), and unusually low amounts of vitamin A which is essential for vision, reproduction, and the maintenance of skin and absorptive surfaces of the body. This indicates that the gulls are being stressed. But at this time the ultimate effects of these chemical changes upon reproduction or life span of these birds are not known.

Deformities in birds

In 1972-75, deformities including crossed bills, jaw defects and malformed feet and joints occurred in Double-crested Cormorants, Common Terns, Caspian Terns, Ring-billed Gulls, and Herring Gulls from Lake Ontario, Lake Erie, and the Detroit River. Generally, contaminant levels in the eggs of fish-eating birds throughout the Great Lakes have decreased since the mid-seventies, yet high rates of deformities are still being found in embryos and young Double-crested Cormorants and Caspian Terns in a few areas of high contamination in Lake Michigan. Potential links between contaminants and deformities are currently being investigated in an extensive Canadian-American study, in which the Canadian Wildlife Service is taking part.

Christine Bishop

Double-crested Cormorant with a deformed bill

Contaminants in the Great Lakes

Gull eggs from Lake Ontario and Lake Michigan have been more contaminated than eggs from the other Great Lakes throughout the entire period of monitoring (Figures 3, 4, 5, and 6). Lake Ontario Herring Gull eggs are the most polluted with 2378-TCDD and PCBs, yet Lake Ontario has also experienced the greatest overall reductions of contaminant load in gull eggs since the early 1970s. Lake Michigan Herring Gull eggs have been the most heavily polluted with DDE and dieldrin. They are second only to Lake Ontario in their contamination by PCBs.

Herring Gull eggs from Lake Ontario contained the most 2378-TCDD and PCBs

Lake Superior and Lake Erie have been the least contaminated lakes from 1970 to 1989. By 1989, Herring Gull eggs from Lakes Erie and Huron had almost equal levels of PCBs, DDE, and dieldrin, but levels of 2378-TCDD remain much higher at Channel Shelter Island in Lake Huron than at any site on Lake Erie.

The low contaminant levels in gull eggs from Lake Superior have probably been due to the lack of industrial development on its shores, in comparison with the lower Great Lakes. However, the contaminant levels in Lake Superior eggs have not decreased as fast as in

Low contaminant levels in eggs from Lake Superior reflect the lack of industries on its shores

eggs from the other lakes and this is mainly due to two factors. The removal of contaminants by natural processes is slow in Lake Superior due to its great depth which slows the rate at which contaminants are removed from its food web by sedimentation and other processes. Unlike the other Great Lakes, the source of contamination of that lake has always been the atmosphere, and sources into the atmosphere are difficult to control.

Contaminant trends, 1971 to 1989

1970s

Nineteen years of research has shown that the highest levels of nearly all contaminants occurred in the early 1970s and almost all contaminants have greatly decreased since that time. For some compounds such as DDE, PCBs, and 2378-TCDD, the declines have been dramatic (Figures 3, 4, and 5). An exception to these declining trends has been the pesticide dieldrin. Dieldrin levels have shown the slowest decline and in many areas the 1989 levels remain similar to those in the early 1970s (Figure 6).

The rapid decline of contaminant levels in Herring Gull eggs in the mid and late 1970s was mainly due to regulations that were implemented in the late 1960s and early 1970s restricting the use and production of the organochlorine pesticides (see box on page 8). Coincident with

Figure 3
Trends in average annual concentrations of DDE in Herring Gull eggs at eight colonies on the Great Lakes.

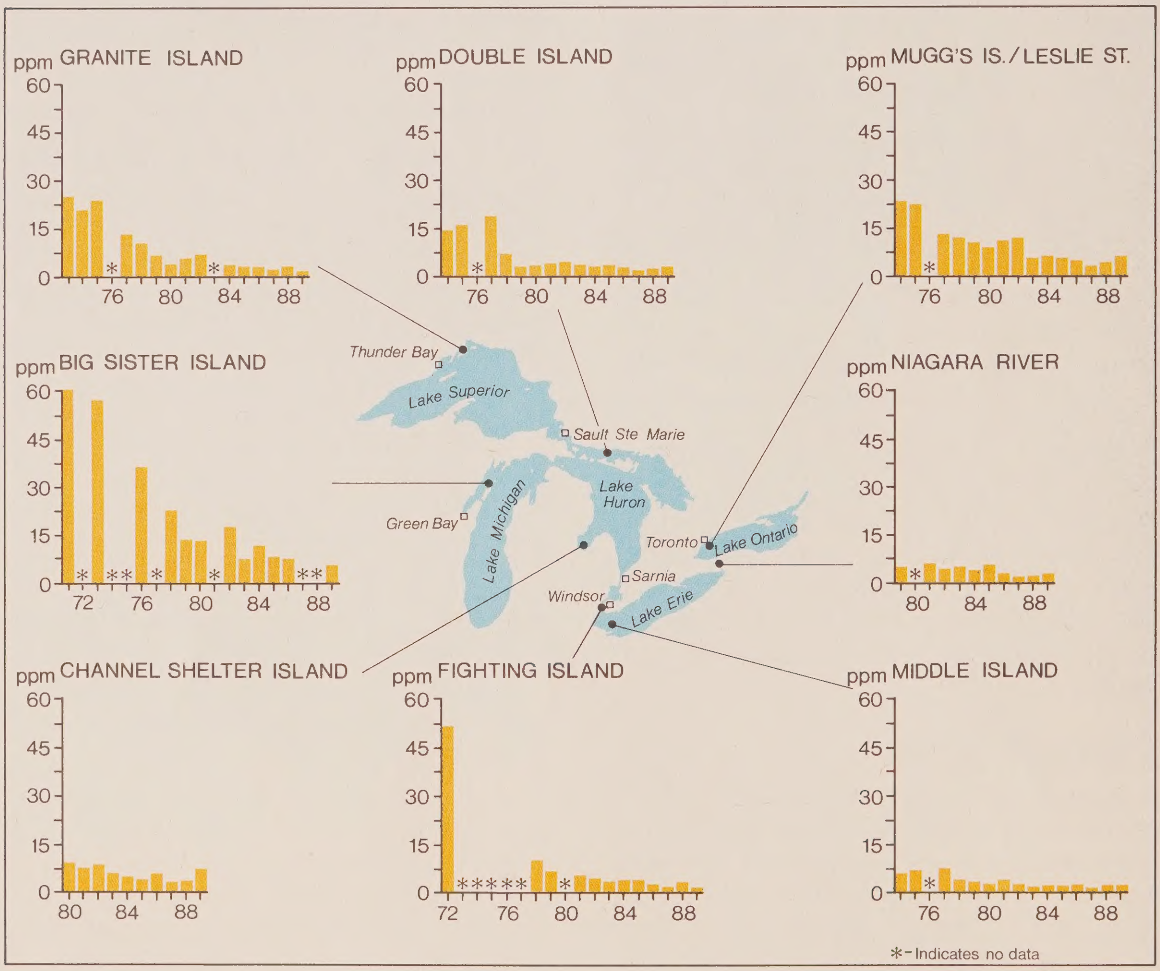
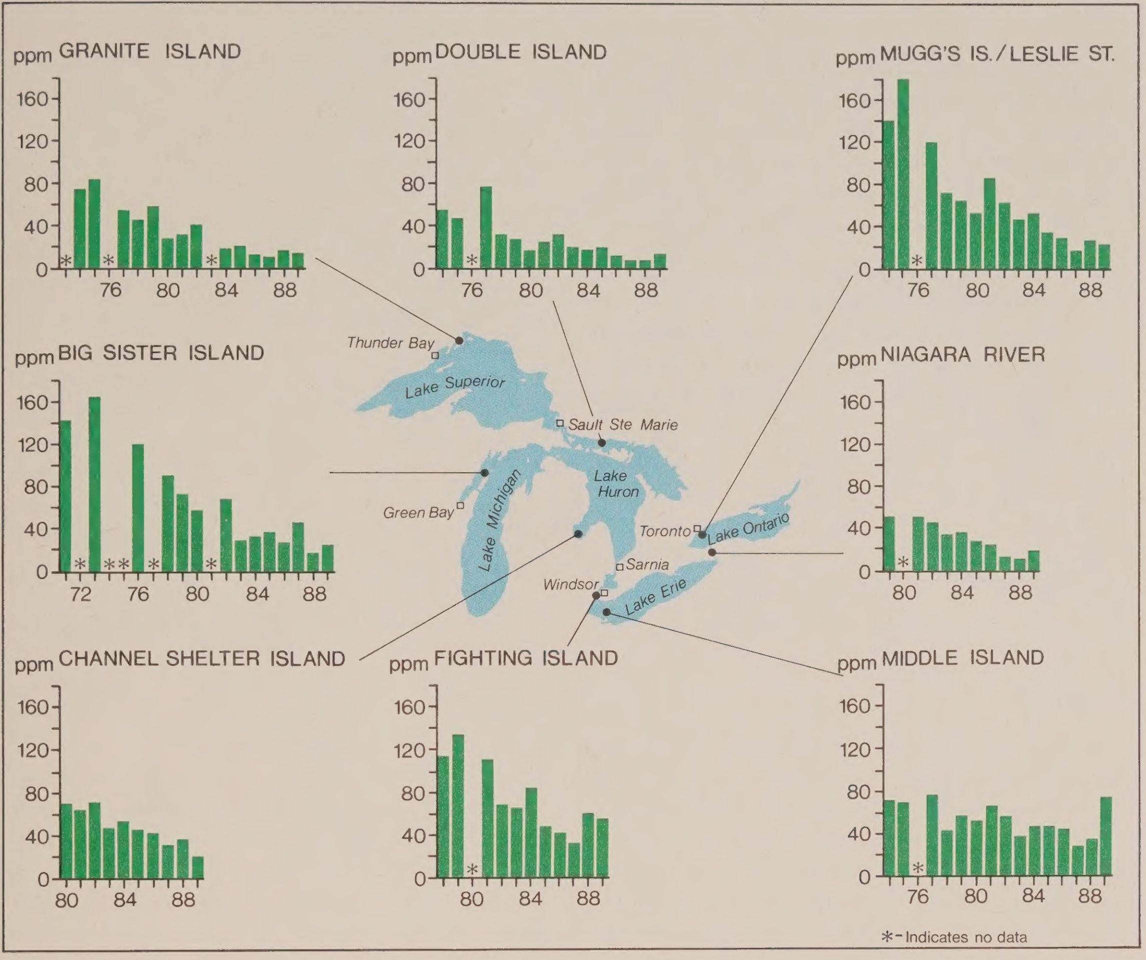


Figure 4
Trends in average annual concentrations of PCBs in Herring Gull eggs at eight colonies on the Great Lakes.



organochlorine pesticide restrictions, PCB production was reduced voluntarily by its manufacturer in 1971. This contributed greatly to the downward trend of PCB contamination in Herring Gull eggs throughout the seventies.

Dioxin levels in Herring Gull eggs also dropped sharply in the 1970s. There were two particular areas with high levels of dioxins in gull eggs, one site on Lake Huron, and another site on Lake Ontario. The eggs from other Great Lakes colonies contained much lower levels.

Although dioxins enter the Great Lakes ecosystem through atmospheric deposition on a broad scale, the most serious local contamination was via industrial effluents in Saginaw Bay, Lake Huron and in Lake Ontario. 2378-TCDD can be formed in minute quantities during the production of 2,4,5-trichlorophenol and can contaminate the end product and the wastewater from manufacturing processes. A chemical plant located in Niagara Falls, New York produced 2,4,5-trichlorophenol and another plant on the shore of the Tittabawasee River which flows into Saginaw Bay produced the herbicide 2,4,5 -trichloro-phenoxyacetic acid, which is made from trichlorophenol. Thus, elevated levels of 2378-TCDD in birds in Lake Ontario and Saginaw Bay can be linked to effluents from previous chemical manufacturing, or waste dump sites associated with this manufacturing. The factories near Saginaw Bay and in

Almost all contaminants have greatly decreased since the early 1970s

Selected organochlorine contaminants

DDE

Dichlorodiphenyldichloroethylene (DDE) is a “metabolite” or breakdown product of a synthetic pesticide known as dichlorodiphenyltrichloroethane (DDT). DDE is produced in most animals when the body attempts to rid itself of DDT.

DDT was introduced for widespread use as an insecticide just after World War II. Most uses of DDT were banned in 1974. Registration of all DDT products was discontinued in 1985. However, the use and the sale of existing stocks of DDT products were allowed until Dec. 31, 1990. DDE is routinely measured rather than only DDT. This is done because DDE is the most fat-soluble of the DDT breakdown products; thus, of all the compounds that make up total DDT (DDT and its metabolites), DDE is the most easily measured in the fat of animals or eggs.

Dieldrin

Dieldrin has been in use since 1948, as an agricultural soil and seed treatment to kill fire ants, grubs, wireworms, root maggots and corn rootworms. In insects and some mammals, dieldrin is also a breakdown product of another pesticide, aldrin, which has been banned. By 1975 dieldrin’s use was restricted, and now it can only be used for termite control.

PCBs

Polychlorinated biphenyls (PCBs) have been in use since 1929. There are 209 PCB isomers which differ from each other in the number and relative position of the chlorine atoms on the biphenyl frame. A small number of the isomers have toxicological properties similar to 2378-TCDD and are thought to account for the bulk of PCB-induced toxicity in animals. Their low flammability made them useful as fire retardants in insulating and heat-exchanging fluids used in electrical transformers and capacitors. The same property made them useful as lubricating oils. They were also used as plasticizers and waterproofing agents and in inking processes used to produce carbonless copy paper. Industrial producers of PCBs voluntarily cut back PCB production in 1971. In Canada, PCB uses were regulated in 1977 and importation of all electrical equipment containing PCBs was banned after 1980.

2378-TCDD

Dioxin is the popular name for a class of organochlorines known as polychlorinated dibenzo-p-dioxins (PCDDs). Dioxins are produced accidentally along with furans or, more accurately, polychlorinated dibenzofurans (PCDFs), which are also organochlorines. Only a few of the 75 PCDDs and 135 PCDFs are highly toxic; others are practically harmless. The most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD), although tolerance to this compound varies considerably among species.

Dioxins and furans are formed either as byproducts during some types of chemical production that involve chlorine and high temperatures or during combustion where a source of chlorine is present. Elevated levels of 2378-TCDD in the environment are linked to effluents from previous 2,4,5-trichlorophenol manufacturing, and to waste dump sites associated with this manufacturing, such as Love Canal. 2378-TCDD also arrives in the Great Lakes as part of airborne particulate material largely from urban areas where municipal incinerators burn a wide range of chlorinated compounds put out with the trash, and from engine exhaust when leaded gasoline or diesel fuel (both of which contain chlorinated compounds) is used. Chlorine bleaching of kraft wood pulp is another source of 2378-TCDD. However, thus far, this process has not been implicated as a major source of 2378-TCDD in the Great Lakes.

Figure 5
Trends in average annual concentrations of 2378-TCDD in Herring Gull eggs at nine colonies on the Great Lakes.

Niagara Falls, New York, discontinued the production of these chemicals in the mid-seventies, with resulting declines in levels of dioxins at these sites.

1980s

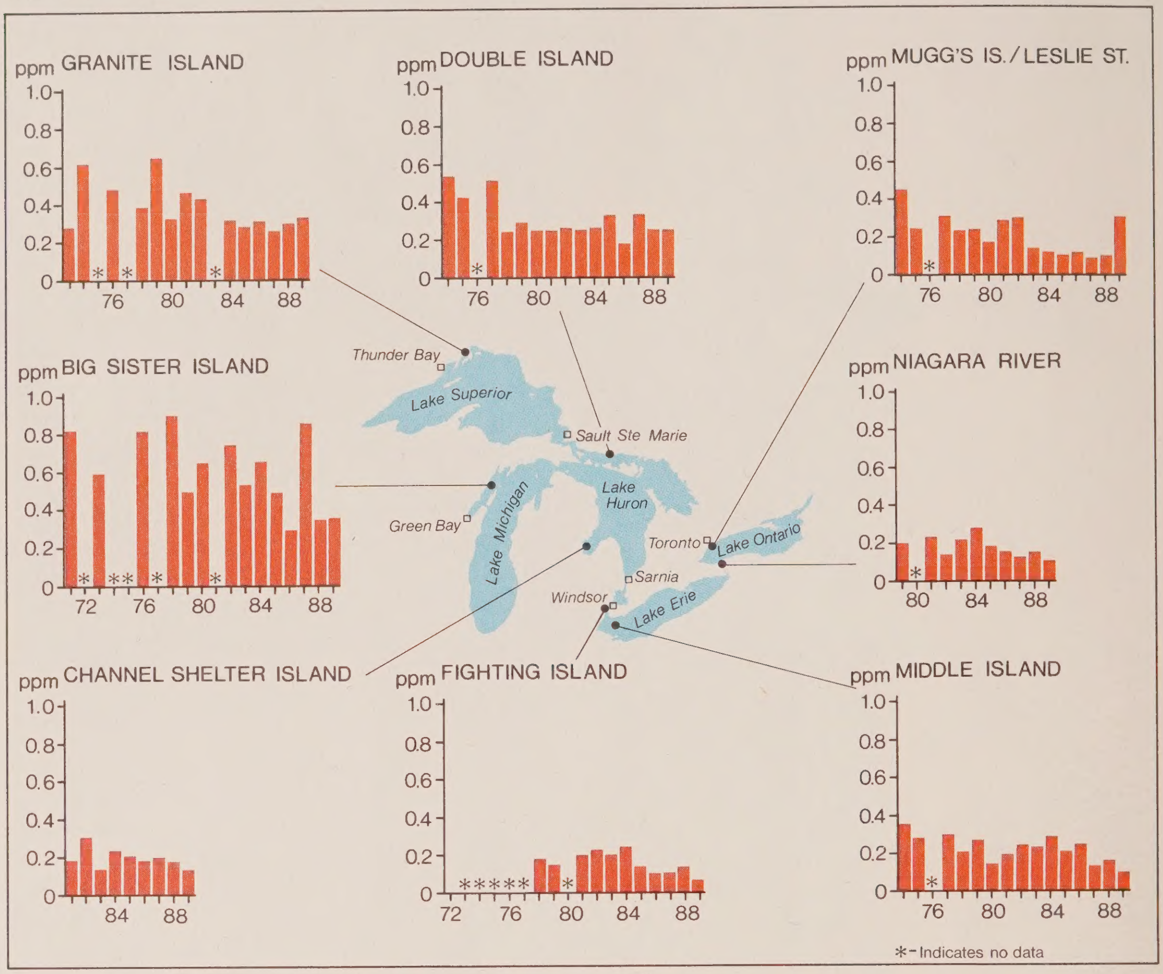
In the 1980s, the contaminant declines have not been as obvious as in the 1970s, and in 1981 and 1982, there was even a brief increase in contaminant levels throughout the Great Lakes. The different rates of change in contaminant levels are due to the different sources of the contaminants in the 1980s compared with the sources in the 1970s. The problems in the 1970s were due primarily to local use and discharge of contaminants and many of these sources have been controlled. In the 1980s, persistent contaminants are still cycling through the Great Lakes ecosystem from less easily controlled sources such as leaching from landfill sites, disturbance of lake sediments, and transport in the atmosphere.

The increase in contaminant levels in Herring Gull eggs during 1981 and 1982 may have been caused by a number of factors: e.g., cyclical changes in fish populations, increases in fresh inputs of some organochlorines to the Great Lakes, and the cycling of contaminants within the lake ecosystem.

Contaminant levels have declined slowly in the 1980's.

Previous dramatic declines in contaminant levels in Herring Gull eggs have immediately followed changes in contamination in fish in the Great Lakes. During the 1970s, contaminant

Figure 6
Trends in average annual concentration of dieldrin in Herring Gull eggs at eight colonies on the Great Lakes.



levels declined in smelt, trout, and spottail shiners in the Great Lakes but, in 1981 and 1982, levels in smelt, a mainstay of the Herring Gull diet, increased again. The specific factor acting to cause the brief rise in contaminant levels in fish and Herring Gull eggs in 1981 and 1982 is still unknown.

Sources of contaminants in the 1980s

Atmospheric deposition

Organochlorine compounds enter the atmosphere when they evaporate or when solid particles are swept up by the wind. The compounds can be blown or settle gradually onto the earth or water surfaces. Other molecules are washed out of the atmosphere with rain and snow.

Both these processes place contaminants directly into the Great Lakes. Contaminants that reach solid ground by these pathways may also eventually enter the Great Lakes from groundwater and runoff of surface water and snowmelt.

Landfill sites and lake sediments

Other processes that cycle organochlorine contaminants are the slow movement of discarded stocks of pesticides and other products from landfill sites into the Great Lakes via groundwater and the disturbance of contaminated sediments. These sources contribute slow but continual contaminant inputs.

Reducing contamination in the 1990s

The reduction of pollution levels in the 1990s appears to be a greater challenge than in the 1970s. The types of contaminant sources occurring in the 1980s are extremely difficult to control. For that reason the levels of pollution in the 1980s and 1990s may not decrease as rapidly as in the 1970s. This is not to say that there are no more direct sources of contaminants. However, these indirect sources of pollutants may now be as important as the direct sources.

Natural processes are currently important factors in lowering the environmental levels of organochlorine contaminants. For example, the natural build-up of sediments in the lakes can bury the more contaminated layers and contaminants will become less available to the food web.

Improved technological controls are being developed to screen even low levels of contaminants from effluents, exhaust systems and smokestack plumes. These challenges must be met in the future by the whole global community if declines in contaminant levels are to be achieved.

Both the Canadian and United States governments have agreed to work together to improve the conditions in the Great Lakes through their commitment to the Great Lakes Water Quality Agreement. The agreement calls for the development of remedial action plans and lake-wide management plans that will detail the extent of contaminant problems on the Great Lakes and implement solutions to control them through the International Joint Commission. Monitoring contaminants in Herring Gull eggs will continue, as will research into the effects of contaminants on the food web in the Great Lakes.

Effects on people

Fish-eating birds have been good sentinels of contamination and biological abnormalities occurring in animals living in the Great Lakes. They "flag" the presence of biologically significant concentrations of chemicals in the Great Lakes that are toxic to developing embryos. These contaminants would be expected to occur in the tissues of any species, including human beings, that eat large numbers of fish from the Great Lakes basin. Obviously there are differences between birds and human beings, so the exact health effects found in the birds are not necessarily predictors of the same health impacts in humans. However, recent studies of infants of mothers who eat large amounts of highly contaminated Great Lakes fish indicate that some developmental effects can occur in the children. Assessment of potential effects of contaminants in human populations is usually based on the available information including the results of toxicological studies in other mammals, studies of highly exposed populations, and the degree of exposure. We should not take the incidences of dead embryos in eggs, deformities, and biochemical changes in birds in the Great Lakes lightly; they are indicators of something amiss in the ecosystem. Other top-predator species in the Great Lakes have demonstrated similar responses. The Great Lakes must be clean enough for all species to live and reproduce normally.

It will be more difficult to reduce pollution levels in the 1990s than it was in the 1970s

The Great Lakes must be clean enough for all species to live and reproduce normally

What is a "ppm", a "ppb", a "ppt"?

Parts per million (ppm), parts per billion (ppb) and parts per trillion (ppt) have become commonly accepted terms used to express pollutant measurements in air, soil, water and tissues. The following list of comparisons should help you picture these quantities of pollutants.

one part per million = one ice cube (5 g) in 5 t ice
one part per billion = one second in 32 years
one part per trillion = one second in 320 centuries

These comparisons indicate how low pollution levels are in some cases. Unfortunately, some chemicals are harmful to animals even at these incredibly low levels.

Bibliography

Gilbertson, M. and R. Hales. 1974. Characteristics of the Breeding Failure of a Colony of Herring Gulls on Lake Ontario. Canadian Field-Naturalist 88:356-58.

Humphrey, H.E.B. 1988. Chemical contaminants in the Great Lakes: The Human Health Aspect. pp. 153-165 in Toxic Contaminants and Ecosystem Health: A Great Lakes Focus, edited by M.S. Evans, New York: John Wiley and Sons, Inc.

Mineau, P., G.A. Fox, R.J. Norstrom, D.V. Weseloh, D.J. Hallett and J.A. Ellenton. 1984. Using the Herring Gull to Monitor Levels and Effects of Organochlorine Contamination in the Canadian Great Lakes pp. 425-452 in Toxic Contaminants in the Great Lakes, edited by J.O. Nriagu and M.S. Simmons. New York: John Wiley and Sons, Inc.

International Joint Commission Council of Great Lakes Managers. 1989. Proceedings of the Workshop on Cause-Effect Linkages, edited by M. Gilbertson. International Joint Commission, Windsor, Ontario.

For further information

Supplementary information on the Herring Gull Monitoring program may be obtained from the following address:

Canadian Wildlife Service
P.O. Box 5050
Burlington, Ontario
L7R 4A6

Information on State of the Environment Reporting may be obtained from the following address:

State of the Environment Reporting
Environment Canada
Ottawa, Ontario
K1A 0H3

Information on contaminants in the Great Lakes may be obtained from the following address:

International Joint Commission
100 Ouellette Ave.
Windsor, Ontario
N9A 6T3

Authors: Christine Bishop and D.V. Weseloh

Published by Authority of the Minister of the Environment

Catalogue No. EN1-12/90-2E
ISBN 0-662-17922-6

Également disponible en français sous le titre: ***Les contaminants dans les oeufs du Goéland argenté des Grand Lacs***

Canada